

FOSSIL PENGUIN BONES FROM MACQUARIE ISLAND, SOUTHERN OCEAN

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WITH APPENDIX BY EDMUND D. GILL³

ABSTRACT: Fossil bones of *Eudyptes chrysolophus schlegeli* Finsch, c. 6000 years old, and of *Aptenodytes patagonica* Miller, c. 4000 years old, from Macquarie Island are compared with recent bones of these species to reveal no significant difference. An account is given of the fossil beds at Finch Creek and of previously unrecorded beds at Bauer Bay. Evidence of an early and hitherto unrecorded colony of *Aptenodytes patagonica* at Bauer Bay is thus established. Comment on the terminology of the penguin skull and humerus is included. An appendix on the geology is provided by E. D. Gill.

INTRODUCTION

Macquarie Island (lat. 54° 30' S., long. 159° 00' E. map Fig. 1) may be conveniently described as 'a mountain range rising abruptly in cliffs directly from the sea, or from narrow low-lying bcaehes' (Mawson 1943). Finch Creek flows southeast into Sandy Bay on the east coast some five to six miles south of North Head. Strata containing fossil penguin bones occur in the south bank, the original find being made at a point just west of the junction with the creek's lowest tributary (Fig. 2). They are now known to extend both west and east of this point.

The first published reference to the bones from Finch Creek is by L. R. Blake, whose extensive geological and topographical notes formed the basis of Sir Douglas Mawson's Report (1943) on Macquarie Island in the Scientific Reports of the Australasian Antarctic Expedition, 1911-14. His note, with sketches, remarks 'bird bones . . . sparsely distributed, . . . in all probability those of a species of penguin, . . . too fragmentary and decomposed to allow of specific determination'. It is not known whether Blake, or anyone else during that period, collected specimens.

Mawson's footnote ('too fragmentary and decomposed to allow of specific determination') may be read as evidence that Blake had collected fragments, that Mawson had seen them ('he handed over to me all his specimens and photographs'), and had considered them not worth

preserving. Alternatively it is possible that Blake, finding only fragments and making no collection, mentioned their condition to Mawson. After a lapse of nearly 40 years a collection of bones was made in 1949 by Dr. A. M. Gwynn and deposited in the National Museum of Victoria.

In December 1957 one of us (McEvey) visited Macquarie Island to study the occurrence, found an extension of the strata, made a further collection, and initiated research on the specimens. During 1962 the other author (Vestjens) spent 12 months on Macquarie Island as biologist. He undertook further study of the Finch Creek occurrence, made the largest collection, found an extension of the strata to the east and discovered previously unknown fossiliferous strata at Bauer Bay. The aims of the present paper are to summarize the stratigraphy, list the fossils and make osteological comments.

PENGUIN OSTEOLOGY

It would appear that no detailed description of the skeleton of either the Royal Penguin (*Eudyptes chrysolophus schlegeli* Finsch) or the King Penguin (*Aptenodytes patagonica* Miller) has been written.

A useful bibliography to the early taxonomic history of the penguins is provided by Coues (1872). Subsequent valuable papers by early workers on the osteology of the group are by Watson (1883), Menzbier (1887) and Pycraft (1898).

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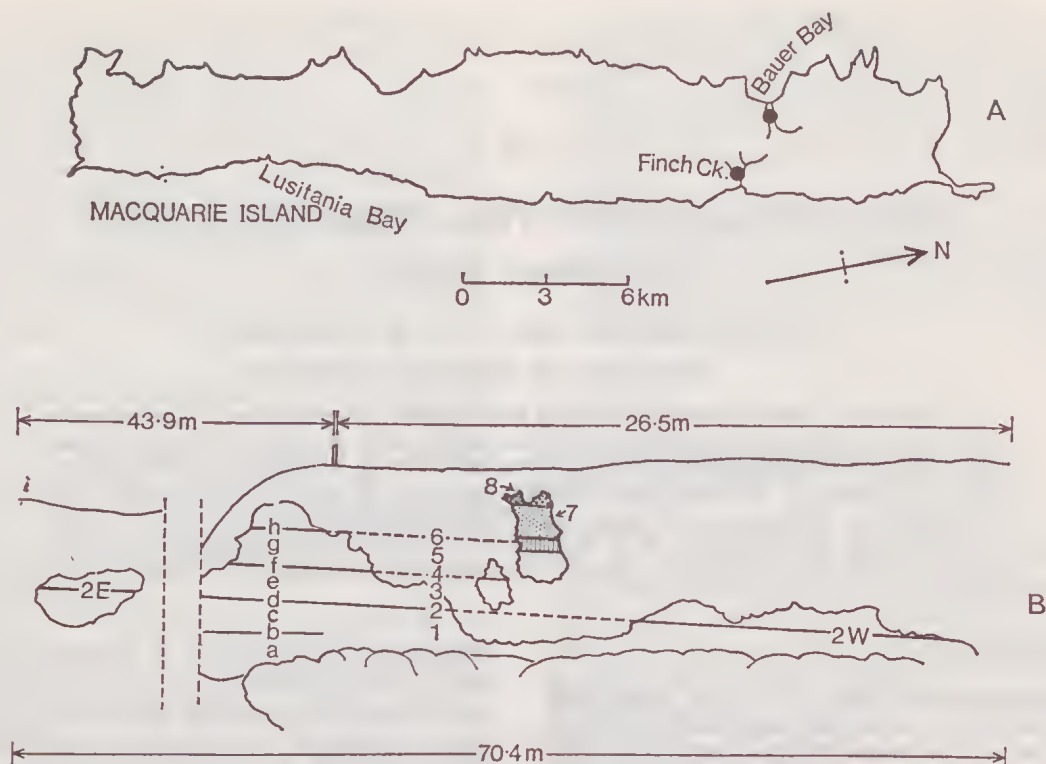


FIG. 1—(A) Macquarie Island showing positions of Finch Creek and Bauer Bay. (B) Finch Creek strata. Lettered as by Blake, numbers by present authors. Included are extensions 2 E and 2 W, and Vestjens' exposed upper beds. (Drawing: F. Knight).

Watson (1883) remarks, 'In the works of none of the authors above named, however [Blumenbach, Brandt, Wagner, Eyton and Barkow], can I find any approach to a complete comparative description of the various species of Penguin, and this deficiency I now endeavour to make good, so far as material at my disposal will permit'. His ensuing account, excellent as it is, discusses eight species including *chrysolophus* from Kerguelen Island and is necessarily somewhat general. A rather more precise treatment of the penguin skull, for example, is provided by Pycraft (1898).

However, full descriptions of skeletons of single species are perhaps not the most pressing need in cases such as this where the morphology of the family, by comparison with that of other families of birds, is so little varied.

In the absence of a full osteological description of the living sub-species *E. c. schlegeli*, for use as a basis for comparison with fossil specimens, the notes of Watson (1883), Pycraft (1898) and Marples (1952) are used as fundamental references and the opportunity is taken to comment upon one or two points of terminology.

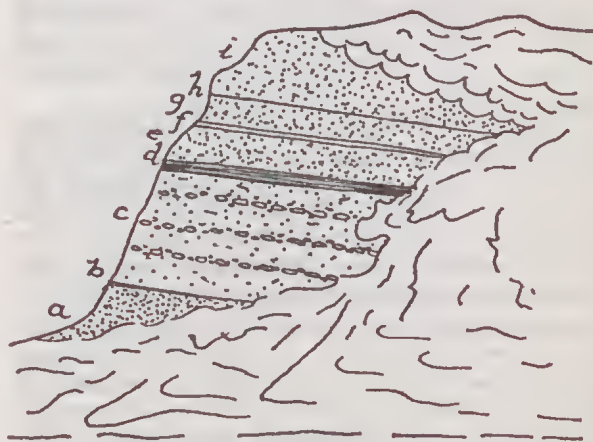


FIG. 2—Strata at Finch Creek. The legend in Mawson reads: 'Fluvio-glacial deposits in Finch Creek. (a) Gravel and Sand; (b) Peaty Mud—1 inch; (c) Coarse Sand Gravel with occasional bird bones—6 ft. 6 inches; (d) Peaty Mud—9 inches; (e) Gravel and Sand—18 inches; (f) Peaty Mud—3 inches; (g) Gravel and Sand—18 inches; (h) Peaty Mud—1 inch; (i) Sand and Gravel—3 feet plus.' (Drawing: L. Arnold, after Blake in Mawson, 1943, Fig. 40 p. 83).

Beddard (1898) lists the family Spheniscidae (Penguins) as being schizognathous in its palatal arrangement and *E. c. schlegeli* typifies this, the vomer being anteriorly pointed, and posteriorly, clasping the basisphenoid between the palatines. The palatines, together with the pterygoids, are not, however, separated by the vomer, but themselves articulate with the basisphenoid. Garrod (1873) lists Impennes (Sphenisciformes) as having holorhinal nasal bones. *E. c. schlegeli* exemplifies this condition. The nasal opening ends posteriorly well anterior to the nasal-frontal hinge and does not separate the hinge-line of the lateral nasal bars from that of the medial dorsal bar (Bock & McEvey 1969, p. 205). The skull is prokinetic (cf. Bock 1964). The posterior margin of the nasal opening is incidentally rounded.

Bock (1960) pointed out that a secondary articulation of the mandible is present in *Aptenodytes* and remarks that 'it is absent (?) in others such as *Spheniscus*'.

Examination of skulls that have not been prepared with particular attention to this region can be very misleading because capping pads on articular surfaces are frequently removed and quadrates and mandibles are often found to have dried in positions which might or might not be natural and therefore provide uncertain evidence as to the amount of space normally found between the medial process of the mandible and the lateral/medial process of the basitemporal plate, in the species concerned. Thus in specimens of the same species one can find dried skulls showing gradations from obvious evidence of secondary articulation by the actual abutting of the processes mentioned with surfaces clearly shaped for

articulation, to doubtful evidence where although the surfaces correspond in shape for possible articulation, the gap between them is so wide (possibly caused by the quadrate drying in a twisted position) that they can be brought closer together only by force disturbing the natural position of the bones. Soaking the skull to produce freer movement is unsatisfactory because even then one cannot be certain that the quadrate is in a truly normal position, and the complex shape and action of this bone are such that a very slight movement of it has a magnified effect upon the position of the medial process of the mandible in relation to the basisphenoidal plate. Even when the specimen shows actual contact between the basitemporal process and the mandible one cannot be certain that the quadrate is in the exact position it would hold in life. From the limited number of recent skulls examined (i.e. examples carrying quadrates and mandibles intact) the authors, pending further examination by dissection, tentatively classify the subspccies *E. c. schlegeli* as exhibiting secondary articulation, but suggest that it is not as well developed as in the genus *Aptenodytes*.

For general details of the skull the notes by Pycraft (1898) are particularly relevant. It may be noted that the 'temporal crest' of Watson appears to be the 'squamoso-parietal wing' or 'plate' of Pycraft. The edge of this forms a continuation of the supraoccipital (lambdoidal) ridge. In the basioccipital region Pycraft's 'mammillary process(es)' (p. 961) is the medial process

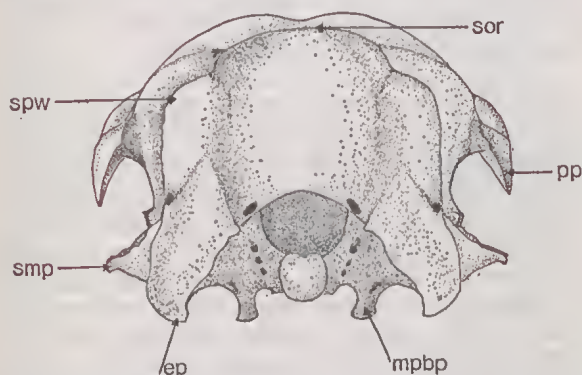


FIG. 3—Diagrammatic sketch of skull of *E. c. schlegeli*, posterior aspect. sor = supra-occipital (lambdoidal) ridge, spw = squamoso-parietal wing, pp = postorbital process, smp = supra-meatic process, ep = exoccipital process, mpbp = medial process of basitemporal plate. (Drawing: L. Arnold.)

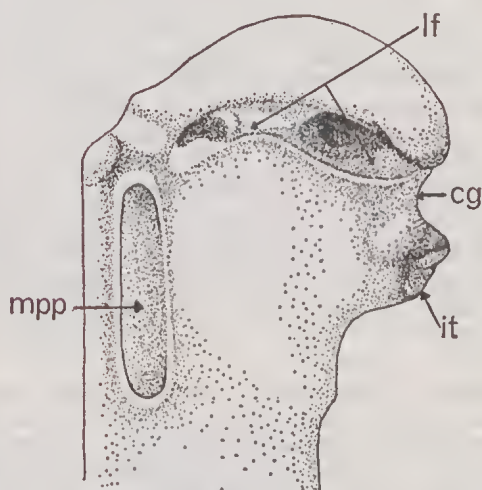


FIG. 4—Diagrammatic sketch of head of humerus of *E. c. schlegeli*, ventral aspect. lf = ligamental furrow, cg = capital groove, it = internal tuberosity, mpp = insertion of *M. pectoralis primus* (= major). (Drawing: L. Arnold.)

of the basitemporal plate. The terminology applied to bones in this region has been confusing in the past and Fig. 3 illustrates some of the names used in the present paper. (See also Bock 1960, pp. 38 and 40.)

Concerning the humerus (see Fig. 4) it is of interest to note the terminology used by Watson (1883) and Marples (1952). The crescentic form of the caput or head of the humerus mentioned by Watson is seen when the head is viewed end-on. The 'horizontal groove which affords attachment to the capsular ligament of the shoulder joint' of Watson (p. 29) and the 'capsular groove' of Marples (p. 17 and diagram p. 9) are the 'ligamental furrow' of Howard (1929) and, as a more recent example, Bock and McEvey (1969).

The 'horizontal groove' of Watson (p. 29) and 'a slight groove' of Marples (under 'Shape of Capsular Groove', p. 17) both appear to be the 'capital groove' of Howard, Bock and McEvey and others, and 'the incisura capitis' of Newton (1893-6, p. 439).

In many birds, e.g. Turnix, the ligamental furrow and capital groove are distinctly separated by a ridge. In *Eudyptes c. schlegeli* they are virtually continuous though running at different angles and only the narrowing of the ligamental furrow separates them. In *Aptenodytes*, as Marples points out, there is even less separation between the two regions.

Also in the wing bones it may be noted that the 'ulna carpal' bone of Watson (1883) is the 'pisoulnare' of Bellairs and Jenkin (1960). In the carpometaarpus the interpretation of the metacarpals varies, that used by Watson and Marples differing from that given by Bellairs and Jenkin in the numbering of metacarpals 1, 2 and 3. The numbering as given by Marples is accepted here.

The present study centres on fossil bones of *E. c. schlegeli* known to be 6000+ years old. The biological problem is to determine whether evolutionary change in the species has occurred during this period. The bones provide an opportunity for osteological examination and analysis of measurements, on the basis of comparison of fossil with recent bones. The study is carried further with an examination of fossil bones of *Aptenodytes patagonica*.

Bones of both species were found on Macquarie Island at both collecting sites, Finch Creek and Bauer Bay (Fig. 1A). Since the majority of bones from Finch Creek were of *E. c. schlegeli* (see Table 1), this species is discussed in connection with this site. Similarly, *Aptenodytes patagonica* is discussed in connection with the Bauer Bay site, where its bones were found more abundantly than those of *E. c. schlegeli* (Table 3).

FINCH CREEK SITE

The fossil beds are exposed in the south bank near its junction with the lowest tributary and east to the beach. The bank is overgrown with Macquarie Island Cabbage *Stilbocarpa polaris*, Tussock Grass *Poa foliosa* and Fern (Pl. 8, figs. 1-4). The acidic ground water has decomposed bones. A path several feet wide made by Royal Penguins (Pl. 8, fig. 1) along the creek bank at about mid-height provides a platform from which the most productive stratum can be reached. The stratigraphic succession is shown in Fig. 1B. Mawson (1943), Ivanac (1948) and Law and Burstall (1956) comment on the geology.

A sample of the bones of the Royal Penguin from strata (d) and 2 W from the McEvey and Vestjens Collections was assayed by Professor Kigoshi (GaK- 643) as $6,100 \pm 120$ y. B.P.

FINCH CREEK COLLECTIONS

The stratigraphic occurrence of these Collections is listed in Table 2.

Gwynn Collection: Bones of *E. c. schlegeli* (Table 1) were taken from Blake's section in 1949. They comprise leg bones, vertebrae, carpo-metacarpal, coracoids, humeri, pelvic girdle parts and cranial parts.

McEvey and Whitten Collection: This was made on 13th and 17-18th December 1957. The most significant event was finding an extension of Blake's fossiliferous stratum (d) some 70 m upstream (see Pl. 8, fig. 2). Most of the fossils collected were obtained from Blake's stratum (d) and its western extension. An unsuccessful search for 300-400 m upstream was limited to exposed patches and sites selected at random. Many specimens crumbled at touch. A few bones of species other than penguins were collected but are excluded from the present study.

Vestjens Collection: Several visits were made during 1962 and Messrs. Pederson and Vestjens searched for extensions of the known fossil area. The creek was examined on both sides for approximately 800 m west of the tributary by digging at least every 9 m. The top of the coastal cliff, north of the creek, was searched along approximately 91 m and places approximating in height to the known fossil strata were extensively checked. The banks of the tributary south of Blake's section, and the south bank of Finch Creek east of Blake's section were also examined. Searching was difficult because of the thick plant cover and the top layer of peat. A layer was found in the south bank of the Creek east of the tributary, approximately 43 m from the stake inserted by McEvey (Pl. 8, fig. 4) above the

Blake's Section			Fossils	Vestjens' Section			Fossils
i. Sand & gravel	91	cm plus	None	119	cm	}	Some bones
h. Peaty mud	2.5		None	28			
g. Gravel & sand	48		None	61			
f. Peaty mud	7.5		None	52			
e. Gravel & sand	48		Some bones	85			
d. Peaty mud	23		Some bones	20 ±			Numerous bones
c. Coarse sand gravel	198		Some bones	Checked for 152 cm			Some bones
b. Peaty mud	2.5		—	—			—
a. Gravel & sand	—		—	—			—

centre of Blake's section. By this discovery the known fossil area was increased to an overall length of c. 70 m. Collecting was done at Blake's section but the material was saturated and difficult to dig out. Blake's stratum (d) contained in addition, seeds of *Stilbocarpa polaris* at a depth of c. 20 cm. The main collecting was done in stratum 2 W. From McEvey's stake this layer extended for about 26.5 m and averaged about 20 cm in depth with a maximum of 24 cm. At the end of the extension the layer dwindled to 5 cm in depth and no fossils were found in it. Fossils in this layer were well preserved and Pl. 8, fig. 3 shows them *in situ*.

A new (Vestjens') section, on the McEvey extension of Blake's section was exposed c. 8 m west of the stake. It is shown by white squares at right of Pl. 8, fig. 4 and is also shown in Fig. 1B. A comparison of Blake's section (Fig. 2) and Vestjens' section is shown above.

E.c. schlegeli

OSTEOLOGICAL EXAMINATION (Table 5): The fossil bones (Table 1) and recent bones examined and compared were the humerus, radius, ulna, pisoulare, carpometacarpus, phalanges of manus, coracoid, clavicle, scapula, femur, tibio-tarsus, tarso-metatarsus, phalanges of pes, ilia-ischia, synsacrum, sternum and skull.

Particular attention was given to muscle scars, conformation of condyles, processes, and fossae, and to any other features in which change, where it has occurred, would be readily discernible. Careful examination of all aspects of the bones, however, reveals a marked individual variation in many characters in both fossil and recent forms. Within this variation in size and conformation one can easily find fossil and recent bones matching so closely that any differences found are likely to be merely individual ones.

This, broadly, is the conclusion reached by osteological examination. The only exceptions occurred in connexion with the humerus and coracoid. In the humerus the groove of insertion of *M. pectoralis primus* tends, at its distal end, to be wider and shallower in the fossil than in the recent. Though very small in extent this difference is distinctly perceptible. The series of measurements shows that

the left fossil humerus averages 3.5 mm against 3.1 in the recent bones. The right fossil humerus averages 3.9 mm against 3.25 in recent bones. This incidentally displays an interesting, though (from the evolutionary viewpoint) not necessarily significant larger insertion on the right than on the left in both fossil and recent forms.

In the coracoid the inclination of the coracohumeral surface (i.e. the angle of turn from the longitudinal axis of the bone) gives the appearance of a slightly greater inclination in recent than in fossil bones. A technique devised for measuring this showed only 0.4° difference of inclination in the left coracoid and only 0.5° difference in the right. The variation of surface features affecting this measurement render it difficult to obtain stable figures.

STATISTICAL ANALYSIS: Tables 5 and 6 show (i) extreme and mean values of several measurements of each bone and (ii) variances for two selected measurements of each bone.

On the level of simple comparison of means (fossil v. recent) for all measurements, it will be found that no clear pattern emerges to distinguish fossil from recent bones, though one can find a very slight tendency for the shafts of bones to be narrower in recent than in fossil forms.

Examination of the variances as calculated for two selected measurements of each bone, though a significant difference for both measurements of the humerus may be noted, reveals in general no significant difference between fossil and recent bones. The variances mentioned in connexion with the humerus are not considered to alter the overall conclusion. There is a tendency for the Finch Creek sample to show greater variance than does the recent sample, but this does not occur at a significant level.

The statistical analysis is therefore in accord with the osteological examination, supporting the conclusion that no significant change in the osteology of the species has occurred.

It should be noted that the recent bones, though all collected at the north end of the island, could, on the basis of recorded knowledge of penguin movement, include specimens from any colony round the island. It seems reasonable to assume that birds providing the specimen bones from the Finch Creek population of earlier times could, for the same reasons, represent colonies other than the Finch Creek one. On these grounds the comparison between the two collections is considered justifiable.

BAUER BAY SITE

The only present day colony of the King Penguin (*Aptenodytes patagonica*) at Macquarie Island is on the southeast coast at Lusitania Bay.

In October 1962 Vestjens, searching for areas similar to the coastal flat at Lusitania Bay, found the first fossil humerus of a King Penguin at Bauer Bay (Fig. 1A). In November and December fossils were collected from seven places (Fig. 5), which suggested that a colony had been situated between the two unnamed creeks at the northern end of the Bay.

A sample of 330 g of small parts of the fossil bones was assayed by Professor Kigoshi (GaK 644) as $3,980 \pm 140$ y. B.P.

THE KING PENGUIN AT MACQUARIE ISLAND

The known history of the King Penguin at Macquarie Island since its discovery is outlined by Mawson (1943). 'There now exists only one rookery, located at Lusitania Bay', he states. 'They have been exterminated from other areas as a result of uncontrolled exploitation for blubber oil'.

The following extracts from Mawson's account (p. 39 et seq.) trace the stages of this extermination.

When the Island was discovered there were in existence at least two very large breeding communities. That at Lusitania Bay was vastly greater than it is today, and at the North-End Isthmus there was a second, probably still greater, congregation of birds . . .

A. Hamilton, in his account of life on the Island, states that a large King Penguin rookery was reported at the North End by Bennett in 1815. In 1820 Bellingshausen, who called at the North End but did not visit Lusitania Bay, describes landing amongst a dense population of King Penguins.

A. Hamilton, in 1894, and H. Hamilton, in 1911, both found masses of King Penguin bones buried under drifted sand on the Isthmus, supplying evidence consistent with the former existence of this King Penguin rookery. Probably within thirty years of Bellingshausen's visit, this entire community had been wiped out, for by the year 1820 fur seals were so scarce that the energies of the sealers were mainly devoted to the production of blubber-oil. Production of this oil, apart from that proceeding from the whale fisheries, was firstly obtained by the slaughter of sea-elephants, and secondly from the wholesale destruction of penguins . . .

At the time of Professor Scott's visit (1880) the rookery at Lusitania Bay was still on a grand scale. It was even so when A. Hamilton (1894) reached the Island. He stated that when anchored in 15 fathoms off Lusitania Bay, thousands of King Penguins played around the ship. On shore nearly the whole of the Lusitania Beach . . . and from the

crown of the beach to the hills, was occupied with Kings packed so closely that there remained unoccupied only a space of about 1½ feet in width surrounding each bird. The total area of the rookery he estimated at 30 to 40 acres . . .

In 1895, when Bickerton spent a short time with the sealers, there was still a very large penguin population at Lusitania Bay, for he wrote of them: 'When we reached the rookery the penguins were there in countless numbers' . . .

It must have been soon after Bickerton's visit that a great assault was made upon them, leaving only a remnant which has been and still is in danger of complete extinction. Owing to the fact that only one egg is laid each year, this bird is very slow to increase its numbers . . .

At the time of our occupation (1911) the sealers had ceased to operate at Lusitania Bay . . . however . . . sealers continued to visit Lusitania Bay annually to collect and store for food large quantities of the eggs of the King Penguin . . .

The rookery at Lusitania Bay is the only community of these birds existing within the great sweep of Southern Ocean between Heard Island and Tierra del Fuego. It now comprises about 5000 birds, a mere shadow of its former population.

(Carriek (1957) remarks: 'A large colony of King Penguins at the Isthmus, the narrow neck of land near the north end . . . was wiped out [by sealers] but the other colony at Lusitania Bay near the south end still flourishes.'

Location of the fossils at Bauer Bay suggests that about 4,000 years ago, colonies of King Penguins at Macquarie were either more numerous than, or differently situated from those mentioned in the recorded history of this species.

DESCRIPTION OF FOSSIL SITES

The area within which the fossils were found was 186 m from north to south, 148 m from east to west, and 210 m from the Bauer Bay beach (Fig. 5). No digging could be done on the western part and it is possible that the fossiliferous strata extend in this direction but have been covered by a past landslide. A layer of large pebbles c. 25.5-33 cm in diameter, which represents a top stratum with fossils, extends down at the western end and disappears under the present bedding.

Five of the fossil sites were found along the present 'First Northern Creek' and one at the 'Second Northern Creek' (Fig. 5). They were on creek-bends where water had denuded sand from the outer curves, exposing bones. The largest site was found in a curve of an old creek bed (Fig. 5, D). Here the section exposed (Fig. 6) was half-moon in shape and 35 m long.

Taylor (1955, pp. 86-7) states of this area, 'The sub-soil is sea-worn sand (fragmented

basalt) formed under water. After the ice age, as the raised beach was formed, this sand was elevated above the sea and some of it was blown a little way inland'.

Of soil samples Mr. K. G. Bowen (*in litt.* Jan. 24, 1966) remarks, 'They are all extremely poorly sorted with a very wide distribution suggestive of a fluvial deposition . . . Blake considers them to be fluvio-glacial in origin. Whether the gravel deposits at Bauer Bay are also fluvio-glacial or not, I am not sure'. For grain size analysis, see Table 7.

Two Royal Penguin colonies at present inhabit the top of the fossil area. Plant associations around the creeks consist mainly of *Pleuro-*

phyllum hookeri, *Stilbocarpa polaris* sub-association, and, on the sand dunes, *Poa foliosa*.

FOSSILS AND FOSSIL LAYERS

The fossils, soft saturated and readily crumbling, were situated indiscriminately, but generally represented complete skeletons rather than random bones, except in the lower layers. This, however, could mean that only the stronger bones of the lower layers, e.g. humerus and femur, were preserved.

The section of site D (Fig. 6) can probably be taken as a section representing the other sites, too, there being only very slight differences between them. It seems that the layers have been

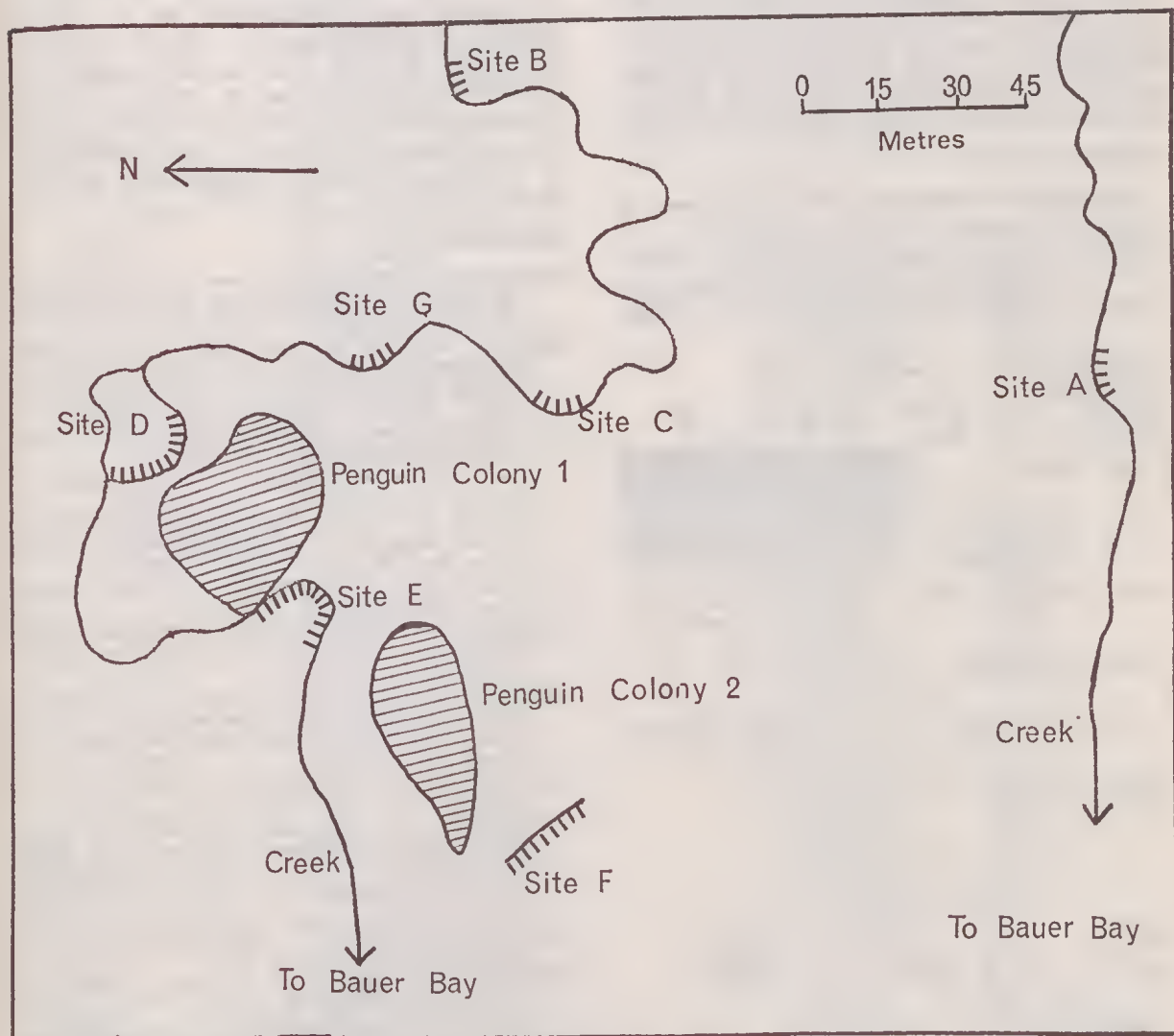


FIG. 5—Fossil sites (A-G) at Bauer Bay, and sites (1 and 2) of present colonies of *E. c. schlegeli*. (Drawing: L. Arnold.)

pushed up under the present colonies (1 and 2, Fig. 5) of Royal Penguins. The pebble layer starts on a lower level under colony 2 (sites F and E) and rises to the level of the inland colony (1) where it has been cut by section site D, and later it appears at site B where it slopes down under the present creek level.

Aptenodytes patagonica

OSTEOLOGICAL EXAMINATION (Table 5): The fossil sample for this species is so limited (Table 3) in material for examination that one can merely group the fossils from Bauer Bay and Finch Creek together, for comparison with recent bones and say that in the humerus, radius, ulna, carpo-metacarpus, phalanx of manus, coracoid, scapula, femur, tibio-tarsus, tarso-metatarsus, phalanx of pes and ilia-ischia, there are no apparent differences to be found in the fossil bones compared with recent bones that cannot be regarded as examples of individual variation.

STATISTICAL ANALYSIS (Table 6): The statistical analysis, based on extremely meagre data, shows no significant difference between fossil and recent bones.

CONCLUSION

Osteological examination and measurement of a limited amount of fossil material of *E. c. schlegeli* show no consistent evidence of evolutionary change. This negative result implies a fair degree of morphological stability in this species

as represented on Macquarie Island during the last 6,000 years.

Results of a similar examination of a much smaller sample of fossil bones of *Aptenodytes patagonica* suggest that a parallel stability has been maintained in this species for the past 4,000 years. The fossil remains of both species provide evidence of former colonies that do not now exist, in certain localities.

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REFERENCES

- BEDDARD, F. E., 1898. *The Structure and Classification of Birds*. Longmans, Green, & Co., London, N.Y. and Bombay.
- BELLAIRS, A. D'A. & JENKIN, C. R., 1960. The Skeleton of Birds. Ch. vii in *Biology and Comparative Physiology of Birds*. Ed. A. J. Marshall. Vol. 1. Academic Press, N.Y. and London.
- BOCK, W. J., 1960. Secondary Articulation of the Avian Mandible. *Auk* 77: 19-55.
- , 1964. Kinetics of the Avian Skull. *J. Morph.* 114: 1-41.
- & McEVEY, A., 1969. Osteology of *Pedionomus torquatus* (Aves: Pedionomidae) and its allies. *Proc. R. Soc. Vict.* 82: 187-232.
- CARRICK, R., 1957. The Wildlife of Macquarie Island. *Aust. Mus. Mag.* XII: 255-60.
- COUES, E., 1872. Material for a monograph of the Spheniscidae. *Proc. Acad. nat. Sci. Philad.* XXIV: 170-212.
- GARROD, A. H., 1873. On the Value in Classification of a Peculiarity in the Anterior Margin of the Nasal Bones of Certain Birds. *Proc. zool. Soc. Lond.* 1873: 33-8.
- HOWARD, H., 1929. The Avifauna of Emeryville Shell-mound. *Univ. Calif. Pub. Zool.* 32: 301-394.
- IVANAC, J. F., 1948. Geological Observations on Macquarie Island. Department of Supply and Shipping. Bureau of Mineral Resources, Geology and Geophysics. Report No. 1948/39. Geological Series No. 15.
- LAW, P. G. & BURSTALL, T., 1956. Macquarie Island ANARE Interim Reports 14.
- MARPLES, B. J., 1952. Early Tertiary Penguins of New Zealand. Append. by H. J. Finlay. *N.Z. geol. Surv. Palaeont. Bull.* 20.
- MAWSON, D., 1943. Macquarie Island, its Geography and Geology. *Australas. Antarctic Exped.* 1911-14, *Scientific Reports Series A*, Vol. V.

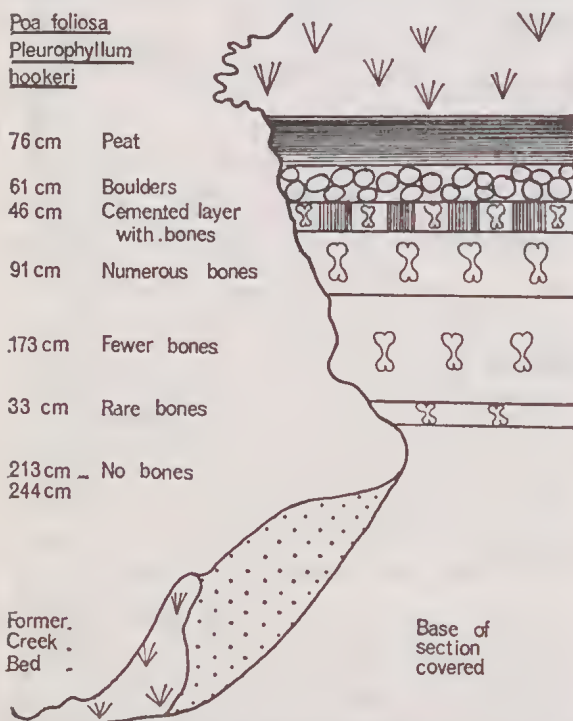


FIG. 6—Section of fossil site D and Bauer Bay. (Drawing: L. Arnold.)

- MENZBIR, M. A., 1885. Comparative Osteology of the Penguins as a basis for a subdivision of the class Aves (In Russian) *Imperatorskii Moskovskii Universitet. Ucheniia Zapiski*, etc. V. V. No. 4.
- NEWTON, A., 1893-6. *A Dictionary of Birds*. Adam and Charles Black, London.
- PYCRAFT, W. P., 1898. Contributions to the Osteology of Birds Part II. Impennes. *Proc. zool. Soc. Lond.* 1898: 958-89.

- TAYLOR, B. W., 1955. The Flora, Vegetation and Soils of Macquarie Island. *ANARE Reports Ser. B. Vol. II Botany*.
- WATSON, M., 1883. Report on the Anatomy of the Spheniscidae collected during the voyage of H.M.S. Challenger. In *Challenger Report*, Sir C. W. Thomson and J. Murray, Zoology Vol. VII. London.

TABLE 1

E. c. schlegeli: FOSSIL BONES COLLECTED AND EXAMINED

	Number in N.M.V. Collection Register
FINCH CREEK	
41 Humerus	B6226, B6230, B9644, B9657
14 Radius	B9648, B9661
19 Ulna	B6225, B9649, B9662
11 Pisoulnare	B10582
17 Carpometacarpus	B6225, B9650, B9663
15 Phalanx of manus	B9675, B10583-5
49 Coracoid	B6226, B9653, B9666
18 Clavicle	B6225, B9652, B9665
11 Scapula	B6225, B9670
61 Femur	B6224, B6230, B9645, B9658
47 Tibio-tarsus	B6224, B9646, B9659
17 Tarso-metatarsus	B6226, B9647, B9660
75 Phalanx of pes	B6225, B9671-2
28 Ilium-ischium	B6225, B9656, B9669
24 Synsacrum	B6227, B9655, B9668
16 Sternum	B9651, B9664
59 Skull (including 39 bill pieces)	B6226, B6236, B9654, B9667, B9676, B9677
53 Vertebra	B6225, B9673-4
2 Pygostyle	B10586
13 Quadrate	B9672
2 Unidentified Bones (fragments)	B6224
BAUER BAY	
10 Humerus	B10574
1 Radius	B10581
4 Coracoid	B10577
4 Femur	B10579
7 Tibio-tarsus	B10578
3 Ilium-ischium	B10576
3 Synsacrum	B10580
2 Vertebra	B10575
COLLECTIONS	
Gwynn:	
Finch Creek 1949	B6224-7, B6230, B6236
McEvey & Whitten:	
Finch Creek 1957	B9644-56, B9675-6
McEvey/Whitten & Vestjens:	(Collections of vertebrae combined) B9673-4
Vestjens:	
Finch Creek 1962	B9657-72, B9677, B10582-6
Bauer Bay 1962	B10574-81

TABLE 2

E. c. shlegeli: STRATIGRAPHIC OCCURRENCE AT FINCH CREEK

GWYNN COLLECTION: These bones were collected from Blake's strata.

McEVEY & WHITTEN COLLECTION: The bones in this collection were collected chiefly from Blake's stratum (d) and the western extension of this, i.e. stratum 2 W, as exposed by McEvey.

VESTJENS' COLLECTION:

Stratum	No. of Bones	N.M.V. Collec- tion Register
Blake's (d)	1 Radius	B9661
	1 Phalanx of pes	B9672
Blake's (f)	1 Humerus	B9657
	1 Coracoid	B9666
	1 Ilium-ischium	B9669
	1 Synsacrum	B9668
	2 Cranium	B9667
2 W	15 Humerus	B9657
	10 Radius	B9661 (plus one in Vestjens Coll.) B9662
	10 Ulna	
	3 Carpo-metacarpus carpus	B9663
	11 Phalanx of manus	B10583-5
	11 Pisoulnare	B10582
	19 Coracoid	B9666
	8 Clavicle	B9665
	12 Scapula	B9670
	28 Femur	B9658
	12 Tibio-tarsus	B9659
	11 Tarso-metatarsus	B9660
	62 Phalanx of pes (excluding ungual phalanx)	B9671
	11 Ungual phalanx	B9671
	12 Ilium-ischium	B9669
	14 Synsacrum	B9668
	2 Pygostyle	B10586
	8 Sternum	B9664
	8 Cranium	B9667
25	Cranial parts (maxill.-pre- maxill.-artic.- angular-splenic)	B9677
13	Quadrate	B9672
	Vertebra (numerous)	

(Continued next page)

TABLE 2 (cont.)

VESTJENS' COLLECTION:		
Stratum	No. of Bones	N.M.V. Collection Register
4 (as exposed by Vestjens)	1 Humerus	B9657
	1 Ulna	B9662
	1 Coracoid	B9666
	3 Femur	B9658
	4 Tibio-tarsus	B9659
	1 Ilium-ischium	B9669
	4 Sternum	B9664
	1 Cranium	B9667
	5 Cranial parts (maxill.-pre-maxill.-artic.-angular-splenic)	B9677
Unidentified (immediately above 2 W as exposed by Vestjens)	2 Humerus	B9657
	1 Femur	B9658
	3 Tibio-tarsus	B9659
	2 Ilium-ischium	B9669
	1 Cranium	B9667
6 (as exposed by Vestjens)	4 Humerus	B9657
	1 Carpo-metacarpus	B9663
	2 Coracoid	B9666
	1 Femur	B9658
	1 Ilium-ischium	B9669
7 (as exposed by Vestjens)	2 Synsacrum	B9668
	Bone fragments	

TABLE 3

Aptenodytes patagonica: FOSSIL BONES COLLECTED AND EXAMINED

		Number in N.M.V. Collection Register
FINCH CREEK		
3 Humerus		B6229, B10595
1 Radius		B10596
1 Ulna		B10587
2 Carpo-metacarpus		B10588, B10597
1 Phalanx of manus		B10614
2 Coracoid		B6229, B10589
1 Scapula		B10590
1 Femur		B10598
3 Tibio-tarsus		B6229, B10591
2 Tarso-metatarsus		B10592, B10599
1 Ilium-ischium		B10593
1 Sternum		B6229
5 Vertebra		B10594
BAUER BAY		
14 Humerus		B10600
8 Radius & ulna		B10601
3 Carpo-metacarpus		B10602
2 Phalanx of manus		B10603
15 Coracoid		B10604

TABLE 3 (cont.)

	Number in N.M.V. Collection Register
1 Clavicle	B10605
2 Scapula	B10606
17 Femur	B10607
c.57 Tibio-tarsus (chiefly fragments)	B10608
12 Tarso-metatarsus	B10609
12 Phalanx of pes	B10610
1 Ilium	B10611
2 Synsacrum	B10612
3 Sternum	B10613
4 Vertebra	B10615

COLLECTIONS

<i>Gwynn</i> :	
Finch Creek 1949	B6229
<i>McEvey & Whitten</i> :	
Finch Creek 1957	B10587-94
<i>Vestjens</i> :	
Finch Creek 1962	B10595-99, B10614
Bauer Bay 1962	B10600-13, B10615

TABLE 4

KEY TO MEASUREMENTS OF VARIOUS BONES,
SEE TABLES 5 & 6

HUMERUS: A Extreme length, B Internal transverse diameter of tricipital fossa, C Minimum width of shaft between the preaxial angle and the head of the humerus, D Width of the shaft at the preaxial angle, E Minimum width of shaft between the preaxial angle and the distal end of the humerus, F Distance from the outer surface of the radial condyle to the border of the dorsal lip of the dorsal sesamoid groove, G Distance from the outer surface of the radial condyle to the border of the ventral lip of the dorsal sesamoid groove, H Distance from the outer surface of the radial condyle to the border of the ventral lip of the ventral sesamoid groove.

RADIUS: A Extreme length, B Maximum preaxial-postaxial width, C Preaxial-postaxial width at the midpoint of the radial shaft, D Transverse depth of the radial shaft at its midpoint.

ULNA: A Extreme length, B Maximum preaxial-postaxial width (i.e. at proximal end), C Preaxial-postaxial width at the midpoint of the shaft, D Transverse depth at the midpoint of the shaft.

CARPO-METACARPUS (Terminology of metacarpus as used by Marples): A Extreme length of second metacarpal, B Extreme length including third metacarpal, C Width one third from the proximal end, D Width two thirds from the proximal end.

PHALANX OF THE MANUS (Proximal phalanx of the second digit): A Length, B Width.

CORACOID: A Total length, B Width of the shaft at the level of the centre of the coracoidal fenestra but excluding the outer rim of the fenestra (i.e. the shaft only), C Total width of the extreme base at the proximal end.

TABLE 4 (cont.)

FEMUR: **A** Length from the hollow between the head and the trochanter at the proximal end to the hollow between the condyles at the distal end, **B** Maximum width at the proximal end, **C** Maximum width at the distal end, **D** Proximo-distal diameter of the head of the femur, **E** Preaxial-postaxial diameter at the midpoint of the shaft, **F** Dorso-ventral diameter at the midpoint of the shaft, **G** Distance from the hollow between the distal condyles to the point where the preaxio-ventral ridge meets the mid-ventral line of the shaft.

TIBIO-TARSUS: **A** Length from the protruberance on the interarticular area to the centre of the furrow between the distal condyles, **B** Maximum width of the distal condyles, **C** Posterior-anterior thickness of the shaft at the midpoint, **D** Internal-external thickness of the shaft at the midpoint.

TARSO-METATARSUS: **A** Length of the second metatarsal from the proximal hollow to the groove on the distal trochlear surface, **B** Length of the third metatarsal from the proximal convexity to the groove on the distal trochlear surface, **C** Length of the fourth metatarsal from the proximal hollow to the groove on the distal trochlear surface, **D** Maximum width at the proximal end, **E** Width of the tarso-metatarsus at the centre, **F** Maximum width at the distal end.

ILIUM-ISCHIUM: **A** Posterior-anterior diameter of the acetabulum, **B** Dorso-ventral diameter of the acetabulum, **C** Length of the ilio-ischiatic fenestra, **D** Width of the ilio-ischiatic fenestra.

SYNSACRUM: **A** Total length, **B** Width taken between the notches of the parapophysis in the region of the sacral vertebrae.

CRANIUM: **A** Width of the skull between the external surfaces of the postorbital processes, **B** Width of the skull between the external surfaces of the suprameatic processes, **C** Depth of the cerebellar dome, **D** Dorso-ventral diameter of the foramen magnum, **E** Transverse diameter of the foramen magnum, **F** Minimum width of the frontal bone between the supraorbital grooves, **G** Distance between the inner surfaces of the exoccipital processes, **H** Anterior-posterior diameter of the basitemporal plate.

	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D	(No. bones)	E	(No. bones)	F	(No. bones)	G	(No. bones)	H
Finch Cr. (L)	4	73.2-81.0 77.6	10	8.8-10.0 9.1	6	13.2-15.2 14.5	7	15.8-18.0 17.0	6	15.5-17.5 16.8	5	19.5-21.0 20.5	5	22.5-24.1 23.5	5	23.2-26.1 24.9
Recent (L)	9	74.0-78.4 74.9	9	8.9-9.6 9.2	9	12.8-14.6 13.5	9	15.5-17.9 16.5	9	14.9-16.5 15.4	9	19.1-21.3 20.2	9	22.1-25.0 23.8	9	23.6-26.4 25.2
Finch Cr. (R)	14	70.0-82.1 76.7	21	8.5-10.6 9.2	21	13.5-15.1 14.2	16	16.0-18.0 17.0	16	15.8-17.2 16.4	12	19.0-21.0 20.1	14	22.5-24.9 23.1	14	23.9-26.0 24.9
Recent (R)	14	74.0-79.0 76.7	15	8.4-9.4 9.0	14	13.2-15.0 14.0	15	15.8-17.8 16.7	14	15.2-16.7 15.9	14	19.0-21.4 20.5	13	22.5-24.9 23.6	13	24.1-26.0 25.3
Bauer Bay (L)	2	74.5-76.0 75.2	1	9.0	-	(worm)	2	15.5-15.5 15.5	-	(worm)	1	20.5	1	23.2	1	24.0
Bauer Bay (R)	3	74.2-75.0 74.5	1	8.9	3	13.0-13.8 13.4	3	15.5-15.8 15.7	2	14.5-15.1 14.8	3	18.5-19.0 18.7	3	22.0-22.5 22.1	2	23.2-24.0 23.6

E. g. schlereli Humerus

TABLE 5: MEASUREMENTS OF BONES

Measurements throughout in mm; L., left, R., right.

TABLE 5 (continued)

E. c. schlegelii Radius

	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D
Finch Cr. (L)	5	51.6-56.0 54.0	5	14.3-15.5 14.8	4	11.7-15.0 13.2	4	4.0-4.2 4.1
Recent (L)	11	52.0-56.3 53.6	11	13.0-14.8 14.0	11	10.5-12.2 11.4	11	3.4-4.0 3.7
Finch Cr. (R)	6	49.7-53.8 52.2	6	13.0-14.7 13.7	6	11.0-12.8 11.7	6	3.0-4.3 3.8
Recent (R)	11	51.5-57.5 54.1	11	13.0-15.0 14.2	11	10.5-12.1 11.5	11	3.4-4.0 3.7
Bauer Bay (L)	1	53.0	1	12.5 (worn)	1	10.5 (worn)	1	3.5 (worn)

E. c. schlegelii Ulna

	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D
Finch Cr. (L)	11	52.2-57.5 55.0	7	17.0-19.0 17.8	7	14.0-15.5 14.8	7	3.5-4.0 3.8
Recent (L)	12	53.5-58.0 55.9	12	15.1-18.8 17.5	12	13.2-16.0 14.5	12	3.1-4.1 3.7
Finch Cr. (R)	8	53.2-57.1 55.1	9	17.1-18.8 17.8	6	14.0-16.2 15.1	8	3.5-4.1 3.9
Recent (R)	10	54.0-58.1 55.9	10	15.5-18.1 17.4	10	13.1-16.0 14.5	10	3.1-4.2 3.7
Bauer Bay	Nil.							

TABLE 5 (continued)

E. c. schlegeli Carpometacarpus

	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D
Finch Cr. (L)	7	42.1-45.0 43.3	8	44.0-47.0 45.3	7	13.4-15.3 14.4	8	15.0-17.0 15.9
Recent (L)	11	41.5-46.0 43.6	11	43.2-48.0 45.5	11	12.3-14.5 13.6	11	13.1-16.5 15.0
Finch Cr. (R)	8	42.0-47.0 43.5	7	44.5-49.1 46.8	8	14.0-15.8 14.5	8	15.0-17.1 15.9
Recent (R)	11	41.6-46.3 43.5	11	43.2-48.2 45.6	11	12.3-15.0 13.7	11	13.1-16.2 15.1
Bauer Bay	Nil.							

E. c. schlegeli. Phalanx of the Manus = proximal phalanx of second digit.

	(No. bones)	A	(No. bones)	B
Finch Cr.	9	26.8-31.5 29.1	9	9.6-10.8 10.2
Recent	9	28.8-30.5 29.7	9	10.0-10.5 10.2
Bauer Bay	Nil.			

TABLE 5 (continued)

E. c. schlegelii Coracoid.

	(No. bones)	A	(No. bones)	B	(No. bones)	C
Finch Cr. (L)	13	81.9-88.0 84.1	16	10.0-11.5 10.6	5	27.1-31.0 28.6
Recent (L)	12	84.7-90.9 87.5	12	9.8-11.0 10.4	12	27.0-30.4 28.8
Finch Cr. (P)	14	80.9-91.5 86.9	16	9.9-11.9 10.9	6	27.0-30.5 28.2
Recent (R)	10	85.0-90.0 87.7	10	9.6-10.9 10.3	10	26.9-30.8 28.6
Bauer Bay (L)	1	86.0	1	11.5	-	-
Bauer Bay (R)	3	80.5-88.9 83.4	2	9.2-11.0 10.1	1	28.5

E. c. schlegelii. Femur.

	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D	(No. bones)	E	(No. bones)	F	(No. bones)	G
Finch Cr. (L)	15	70.6-76.5 73.4	13	17.0-18.9 17.5	14	15.0-16.0 15.5	13	8.2-9.9 9.0	17	7.2-8.2 7.9	17	7.9-9.2 8.5	12	30.0-36.5 31.9
Recent (L)	12	70.3-75.2 73.3	12	16.1-18.6 17.5	12	14.8-16.9 16.0	12	8.2-10.3 9.1	12	7.0-8.2 7.8	12	7.6-9.5 8.4	12	29.8-34.6 32.1
Finch Cr. (R)	18	70.0-77.0 73.4	14	16.0-18.0 17.0	15	14.8-16.5 15.5	16	8.5-10.0 9.1	17	7.0-8.7 7.4	15	7.8-8.9 8.5	10	30.5-35.0 32.6
Recent (R)	9	70.5-75.4 73.4	9	16.3-18.2 17.5	9	14.5-16.5 15.8	9	8.2-10.1 9.2	9	7.1-8.3 7.9	9	7.9-9.2 8.5	9	29.1-34.9 31.7
Bauer Bay (L)	1	77.1	1	16.9	1	16.0	-	-	1	8.0	1	8.8	1	33.0
Bauer Bay (R)	1	76.0	1	18.0	1	16.8	-	-	1	7.5	1	8.0	1	33.5

TABLE 5 (continued)

<u>E. c. sculegeli.</u>		Tibiotarsus							
	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D	
Finch Cr. (L)	9	114.0-122.7 118.2	10	13.1-15.1 14.4	18	6.5-7.9 7.1	18	7.0-8.0 7.5	
Recent (L)	8	117.0-125.0 120.0	8	14.2-15.5 14.7	8	6.4-7.6 6.9	8.	6.9-8.0 7.4	
Finch Cr. (R)	10	115.5-122.1 119.1	10	13.8-15.2 14.6	14	6.5-8.0 7.0	13	7.1-8.5 7.8	
Recent (R)	6	117.1-126.0 121.1	6	14.5-15.8 14.9	6	6.8-7.6 7.0	6	7.2-8.0 7.6	
Bauer Bay (L)	3	112.5-123.0 116.2	1	16.0	2	6.8-7.5 7.2	3	7.5-8.0 7.8	
Bauer Bay (R)	1	114.5	1	14.4	--	---	1	8.0	

<u>E. c. schlegeli.</u>		Tarsometatarsus							
	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D	(No. bones)
Finch Cr. (L)	6	24.3-27.9 25.6	7	28.5-30.9 29.2	3	25.0-26.0 25.4	7	15.8-18.0 16.8	5
Recent (L)	9	22.5-26.9 25.3	9	27.0-31.8 30.0	9	22.0-26.0 24.7	8	15.1-17.8 16.6	9
Finch Cr. (R)	8	24.8-27.0 26.0	8	28.8-31.0 29.8	5	25.5-25.8 25.6	8	15.7-18.9 17.3	8
Recent (R)	9	23.0-27.1 26.6	9	27.8-32.0 30.3	9	22.5-26.5 24.7	8	15.0-18.0 16.6	9
Bauer Bay	Nil.							14.5-16.6 15.7	8
								20.0-22.5 21.6	8

TABLE 5 (continued)

C

<u>A. patagonica.</u> Humerus																
	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D	(No. bones)	E	(No. bones)	F	(No. bones)	G	(No. bones)	H
Finch Cr. (L) Nil....																
Recent (L)	7	106.2-112.0 108.4	8	12.0-13.0 12.3	8	18.0-20.5 18.5	8	20.9-24.0 22.3	8	19.8-22.0 20.5	5	26.0-29.0 27.0	5	29.0-31.5 29.9	5	31.0-34.0 32.1
Finch Cr. (R)	1	105.0	2	12.5-13.0 12.8	2	18.7-18.8 18.8	2	22.9-23.0 23.0	2	21.0-21.2 21.1	1	26.5	1	29.7	1	31.9
Recent (R)	5	106.8-116.5 111.8	9	11.7-13.0 12.1	9	18.0-20.5 18.9	9	21.5-24.4 23.0	9	19.3-22.5 20.7	5	26.8-29.0 27.5	5	30.2-31.5 30.7	5	31.8-34.0 32.5
Bauer Bay (L) Nil...																
Bauer Bay (R)	2	106.5-108.0 107.2	1	12.0	3	18.2-19.0 18.7	2	22.5-23.0 22.7	3	20.5-21.5 20.8	1	27.1	1	29.6	1	32.0
<u>A. patagonica.</u> Carpometacarpus.																
	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D	(No. bones)							
Finch Creek (L) Nil																
Recent (L)	6	62.0-66.2 64.2	6	64.6-68.5 66.5	5	17.0-20.0 17.8	5	17.9-20.5 18.4								
Finch Cr. (R)	1	63.7	1	66.0	1	18.2	1	19.0								
Recent (R)	2	62.0-64.5 63.2	2	64.5-66.0 65.2	2	17.5-20.0 18.7	2	18.1-20.5 19.3								
Bauer Bay Nil.																

TABLE 5 (continued)

A. patagonica. Coracoid

	(No. bones)	A	(No. bones)	B	(No. bones)	C
Finch Creek (L)	Nil.....					
Recent (L)	Nil.....					
Finch Creek (R)	Nil.....					
Recent (R)	3	124.0-127.0 125.0	3	14.2-15.0 14.5	3	38.0-40.0 39.2
Bauer Bay (L)	1	127.0	2	15.0-15.0 15.0	2	35.0-39.5 37.2
Bauer Bay (R)	-	--	-	--	1	36.5

A. patagonica. Femur

	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D	(No. bones)	E	(No. bones)	F
Finch Cr. (L)	Nil...											
Recent (L)	3	88.0-89.0 88.6	3	23.2-25.5 24.0	3	23.0-25.5 23.9	3	12.0-12.5 12.2	2	10.9-12.5 11.7	2	12.2-13.5 12.8
Finch Cr. (R)	1	83.0	1	23.5	1	23.0	1	12.6	1	11.1	1	11.6
Recent (R)	6	83.0-91.5 86.6	4	23.6-25.5 24.5	5	22.7-25.5 23.6	4	12.0-12.5 12.2	6	10.1-12.2 10.6	6	11.5-13.5 12.2
Bauer Bay (L)	1	90.1	2	23.5-24.5 24.0	2	23.3-25.0 24.1	1	12.5	4	10.8-11.5 11.1	4	12.0-13.5 12.7
Bauer Bay (R)	2	89.0-90.0 89.5	1	25.1	4	23.5-25.5 24.6	1	12.5	1	11.4	1	13.0

A. patagonica. Tibiotarsus.

	(No. bones)	A	(No. bones)	B	(No. bones)	C	(No. bones)	D
Finch Creek (L)	Nil...							
Recent (L)	3	156.0-165.0 161.6	4	21.5-24.0 22.2	4	9.0-10.6 9.6	4	10.1-12.2 10.8
Finch Creek (R)	-	--	1	22.2	-	--	-	--
Recent (R)	7	160.0-171.5 164.7	5	21.0-24.0 22.1	7	9.0-10.6 9.6	7	10.5-12.8 11.3
Bauer Bay (L)	-	--	2	23.1-23.1 23.1	-	--	-	--
Bauer Bay (R)	-	--	4	22.9-24.0 23.7	1	10.5	1	11.6

TABLE 6
MEANS AND VARIANCES OF SELECTED MEASUREMENTS

<i>E. c. schlegeli</i>				
	Sample size	Mean	Variance	Comparison of variances
HUMERUS				
Measurement A				Variances significantly different at 1% level
Finch Creek	18	76.8	9.69	
Bauer Bay	5	74.8	0.503	
Recent	19	76.0	1.92	
Measurement D				Variances significantly different at 5% level
Finch Creek	23	17.0	0.436	
Bauer Bay	5	15.6	0.026	
Recent	19	16.5	0.490	
RADIUS				
Measurement A				
Finch Creek	11	53.0	3.70	
Recent	22	53.9	2.92	
Measurement B				
Finch Creek	11	14.2	0.659	
Recent	22	14.1	0.315	
ULNA				
Measurement A				
Finch Creek	19	55.0	3.33	
Recent	22	55.9	2.35	
Measurement B				
Finch Creek	16	17.8	0.350	
Recent	22	17.5	0.795	
CARPO-METACARPUS				
Measurement B				
Finch Creek	15	45.6	2.12	
Recent	22	45.6	2.74	
Measurement D				
Finch Creek	16	15.9	0.437	
Recent	22	15.1	0.918	
CORACOID				
Measurement A				Variances significantly different at 5% level
Finch Creek	27	85.6	9.14	
Recent	22	87.6	2.64	
Measurement C				
Finch Creek	11	28.4	1.73	
Recent	22	28.8	1.61	
FEMUR				
Measurement A				
Finch Creek	33	73.2	3.57	
Recent	21	73.4	1.92	
Measurement B				
Finch Creek	27	17.3	0.377	
Recent	21	17.6	0.432	
TIBIO-TARSUS				
Measurement A				
Finch Creek	19	118.6	7.34	
Recent	14	120.5	9.39	
Measurement B				
Finch Creek	20	14.4	0.308	
Recent	14	14.8	0.221	
TARSO-METATARSUS				
Measurement B				Variances significantly different at 5% level
Finch Creek	15	29.6	0.692	
Recent	18	30.2	2.49	

TABLE 6 (continued)

<i>E. c. schlegeli</i>				
	Sample size	Mean	Variance	Comparison of variances
Measurement E				
Finch Creek	13	16.5	0.504	
Recent	18	15.8	0.438	
ILIUM-ISCHIIUM				
Measurement A				
Finch Creek	22	11.2	0.227	
Recent	20	11.4	0.392	
Measurement B				
Finch Creek	21	11.7	0.262	
Recent	20	11.1	0.497	
SYNSACRUM				
Measurement A				
Finch Creek	4	90.0	13.5	
Recent	11	89.7	37.0	
Measurement B				
Finch Creek	19	14.8	0.432	
Recent	12	14.8	0.454	
CRANIUM				
Measurement A				
Finch Creek	7	52.5	1.49	
Recent	8	52.6	2.95	
Measurement C				
Finch Creek	10	20.8	1.90	
Recent	7	22.7	1.90	
<i>Aptenodytes patagonica</i>				
	Sample size	Mean	Variance	Comparison of variances
HUMERUS				
Measurement A				
Recent	12	109.8	12.97	
Measurement D				
Recent	17	22.7	1.32	
FEMUR				
Measurement A				
Recent	9	87.3	6.85	
Measurement B				
Recent	7	24.3	0.990	
CARPO-METACARPUS				
Measurement B				
Recent	8	66.2	2.00	
Measurement D				
Recent	7	18.7	1.52	
TIBIO-TARSUS				
Measurement A				
Recent	10	163.8	20.8	
Measurement B				
Bauer Bay	6	23.5	0.286	
Recent	9	22.1	1.27	

Variance (s^2) is the square of the standard deviation (s). Samples include both right and left bones.

TABLE 7
ANALYSIS OF BAUER BAY SOIL SAMPLES

Sample	Md	Q3	Q1	P90	P10	So	Sk	K
A1	0.49	0.62	0.40	0.74	0.34	1.24	1.03	0.37
B2	0.49	0.56	0.42	0.67	0.33	1.15	0.98	0.21
C1	0.49	0.64	0.38	0.82	0.31	1.30	1.02	0.25
C2	0.45	0.53	0.38	0.66	0.32	1.18	0.99	0.22
C3	0.53	0.66	0.42	0.80	0.36	1.25	0.99	0.27
D3	0.49	0.62	0.40	0.72	0.33	1.24	1.03	0.28
D5	0.46	0.58	0.37	0.67	0.30	1.25	1.02	0.27
D6	0.45	0.58	0.38	0.68	0.32	1.24	1.09	0.28
E1	0.45	0.55	0.37	0.66	0.30	1.22	1.01	0.25
F	0.30	0.35	0.25	0.44	0.21	1.18	0.98	0.22
G	0.45	0.57	0.36	0.69	0.24	1.26	1.01	0.23
Bauer Beach	0.29	0.35	0.24	0.42	0.22	1.20	1.00	0.27

Md, median diameter in mm. Q3 and Q1, diameters associated with quartiles. P90 and P10, diameters associated with the 10 and 90 percentile measures. So, sorting = $\frac{Q3 - Q1}{Q1}$ and is a measure of the spread of the distribution. Values less than 2.5 are well sorted. Sk, skewness = $\frac{Q1 - Q3}{(Md)^2}$ is a measure of the symmetry of distribution. A value of 1 represents a perfectly symmetrical distribution. K, kurtosis = $\frac{Q3 - Q1}{2(P90 - P10)}$ is not clearly understood, but provides a measure of the quantity in the maximum plus range for a unimodal distribution.

APPENDIX

GEOLOGY OF FOSSIL PENGUIN BEDS, MACQUARIE ISLAND

By

EDMUND D. GILL

Macquarie Island is the subaerial projection of an elongate sub-oceanic ridge which is of similar proportions and orientation, but many times the size (Summerhayes 1967a, Cullen 1970). This Macquarie Ridge is a linear extension of the New Zealand submarine plateau, and is commonly regarded as an island arc system (Cullen 1967, Summerhayes 1967b, Varne, Gee & Quilty 1969, Houtz, Ewing & Embley 1971). It has been suggested that Macquarie Island is 'ocean floor on land', a segment of Pliocene oceanic crust emerged from the ocean (Anonymous 1969). That Macquarie Island is seated on a platform is important (for the present purpose) because part at least of this would have been bared during the Last Glaciation by eustatic drop in sealevel, so changing the outline and extent of the island.

Although it is a Sub-Antarctic island, Macquarie Island does not accumulate ice under present conditions because it is long and narrow, and stands in an area of high winds. The snow is blown away, and insufficient accumulates to allow

an ice cap to form. For the same reason it could not have formed an ice cap of sufficient magnitude to cause detectable isostatic depression in the Last Glacial. This simplifies the interpretation of the Fossil Penguin beds in that no complications from isostasy are present.

SEDIMENTOLOGY

Finch Creek flows into Sandy Bay (note name) on the east side of Macquarie Island, and its mouth is accordant with present scalelevel. It has incised at least 9 m through a deposit of well-stratified, lightly compacted postglacial sediment which has the surface characteristics of a more or less flat floodplain terrace. A basal gravel and sand is followed by peaty mud, and this cycle is repeated three times with a topmost bed of sand and gravel (Mawson 1943, p. 83). Another section shown by Mawson has disturbed beds. The succession indicates a sharp alteration in the dynamics of deposition. Only a turbulent stream flowing over a short floodplain from a steep terrain could deposit the ill-sorted sands and the gravels which include quite large pebbles. On the other hand, only still waters could deposit the peaty muds. The suite of sediments appears from the photographs to be fluvial, or fluvial and lacustrine, but not fluvioglacial as suggested in the literature.

PROVENANCE OF FOSSILS

The penguin bones are well preserved. The photographs show that the bones are not lying parallel to the bedding planes, but as a group are rather randomly oriented, with angles up to 50°. In a peaty mud facies, bones cannot be transported as the dynamics are too low, nor can they be deposited at such angles. In the sand-gravel facies, however, both these processes are normal. Where bones occur in the mud facies they are either intrusive or repositioned due to bioturbation caused by the activities of other animals. There is need for the careful examination of the upper silty peat laminations to ascertain which is the case at Macquarie Island.

CHRONOLOGY

While only one horizon (c.6 m above creek and sealevel) is dated in the Finch Creek deposit (6100 ± 120 y. B.P., GaK-643) and one horizon at Bauer Bay (3980 ± 140 y. B.P., GaK-644), these datings nevertheless indicate mid-Holocene age. However, these datings were made on bones wherein contamination can occur. Also, there are isotopic problems with dating at these high latitudes, and as there is no supporting net of dates on the island, they should not be taken as necessarily precise. It would be worthwhile to date a series of samples through the Finch Creek beds as well as to examine carefully the fabric of the various strata. At the same time as dating the various organic fractions present, the proportions of the various isotopes of carbon in the local environment must be ascertained. The Bauer Bay Beds offer an obvious extension of such a programme. We can infer, however, that the valley in which the Finch Creek Beds are emplaced is older than mid-Holocene, which is the age of at least some of the sediments.

At least three sedimentary cycles of sand-gravel and mud occurred, so there must have been an intermittent barrier in the creek that grossly changed the dynamics of the stream waters at the site. The mid-Holocene Thermal Maximum extended from 6000 years ago or

earlier to about 4000 years ago, and was a time of slightly higher world temperatures. Such would perhaps result in a more intense and less protracted seasonal melt and consequent runoff on Macquarie Island. The island's marked tendency to mass movement on steep slopes would be accentuated at such times, and hillslides may have temporarily dammed the creek, permitting peaty mud to be deposited behind the barrier. Another and more likely possibility is the growth of a berm-top sand dune at Sandy Bay where the present-day wave-built berm frequently dams Finch Creek. Such a dune could dam Finch Creek intermittently, and so allow the stillwater sediments to accumulate. The absence of such a dune today is perfectly consistent with the marked destruction suffered by the massive dunes at Bauer Bay.

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REFERENCES

- ANONYMOUS, 1969. Ocean floor on land. *Nature Lond.* 224: 1153.
- CULLEN, D. J., 1967. Island arc development in the south-west Pacific. *Tectonophysics* 4 (2): 163-172.
- , 1970. A tectonic analysis of the south-west Pacific. *N.Z. Jl Geol. Geophys.* 13: 7-20.
- HOUTZ, R., EWING, J. & EMBLEY, R., 1971. Profile data from the Macquarie Ridge Area. In *Antarctic Research Series, Vol. 15, Antarctic Oceanology*: 239-245.
- MAWSON, D., 1943. Macquarie Island, its geography and geology. *Australas. Antarct. Exped. 1911-1914, Sci. Rept. A, Vol. 5*.
- SUMMERHAYES, C. P., 1967a. Note on Macquarie Ridge and the Tonga-Kermadec complex. Are they parts of the mid-ocean ridge system? *N.Z. Jl Sci.* 10: 808-812.
- , 1967b. New Zealand region volcanism and structure. *Nature Lond.* 215: 610-611.
- VARNE, R., GEE, R. D. & QUILTY, P. G. J., 1969. Macquarie Island and the cause of oceanic linear magnetic anomalies. *Science* 166: 230-232.

EXPLANATION OF PLATES

PLATE 8

Figs. 1-2—Finch Creek environs showing extent of beds excluding E. extension. The far right paper marker in Fig. 1 is the far left paper marker in Fig. 2. Penguins are shown on the penguin-path. The worker is at the western extension, i.e. 2 W. Fig. 4 shows Blake's section enlarged and Vestjens' upper exposure indicated by paper markers at right. The stake used as a datum point is just visible on bank directly above the ladder; Fig. 3 shows fossil bones *in situ*, stratum 2 W. Photographs 1 & 2 by A. R. McEvey, 3 & 4 by W. J. M. Vestjens.

PLATE 9

Fossil and recent bones of *E. c. schlegeli**Tarso-metatarsus*

Fig. 1, Finch Cr., R., ventral aspect, B9660 (1), $\times 1.05$; Fig. 2, Recent, R., ventral aspect, B7867, $\times 1.05$; Fig. 3, Finch Cr., L., ventral aspect, B9647 (6), $\times 1.05$; Fig. 4, Recent, L., ventral aspect, B7886, $\times 1.05$ (showing two pairs of matching size).

Humerus

Fig. 5, Finch Cr., R., ventral aspect showing scar of insertion of *M. pectoralis primus*, B9644 (11), $\times .95$; Fig. 6, Recent, R., ventral aspect, B7868, $\times .95$; Fig. 7, Finch Cr., R., dorsal aspect, B9644 (11) $\times 0.95$; Fig. 8, Recent, R., dorsal aspect, B7868, $\times 0.95$.

Radius

Fig. 9, Finch Cr., L., ventral aspect, B9661 (3), $\times 0.8$; Fig. 10, Recent, R., dorsal aspect, B7865, $\times 0.8$.

Ulna

Fig. 11, Finch Cr., R., ventral aspect, B9662 (1), $\times 0.8$; Fig. 12, Recent, R., ventral aspect, B7867, $\times 0.8$; Fig. 13, Finch Cr., L., dorsal aspect, B9649 (4), $\times 0.8$; Fig. 14, Recent, L., dorsal aspect, B7868, $\times 0.8$.

Carpo-metacarpus

Fig. 15, Finch Cr., L., dorsal aspect, B9650 (4), $\times 1.1$; Fig. 16, Recent, L., dorsal aspect, B7868, $\times 1.2$; Fig. 17, Finch Cr., R., ventral aspect, B9650 (9), $\times 1.1$; Fig. 18, Recent, R., ventral aspect, B7866, $\times 1.2$.

Coracoid

Fig. 19, Finch Cr., R., dorsal aspect, B9653 (6), $\times 0.95$; Fig. 20, Recent, R., dorsal aspect, B7868, $\times 0.95$; Fig. 21, as Fig. 19, ventral aspect, $\times 0.95$; Fig. 22, as Fig. 20, ventral aspect, $\times 0.95$.

PLATE 10

Fossil and recent bones of *E. c. schlegeli**Synsacrum*

Fig. 23, Finch Cr., ventral aspect, B9655 (2), $\times 0.8$; Fig. 24, Recent, ventral aspect, B7869, $\times 0.8$.

Femur

Fig. 25, Finch Cr., R., ventral aspect, B9658 (3), $\times 0.95$; Fig. 26, Recent, R., ventral aspect, B7868, $\times 0.95$.

Cranium

Fig. 27, Finch Cr., dorsal aspect, B9667 (1), $\times 0.7$; Fig. 28, Recent, dorsal aspect, W5654, $\times 0.7$.

Sternum

Fig. 29, Recent, anterior aspect, $\times 0.9$; Fig. 30, Finch Cr., anterior aspect, B9664 (1), $\times 0.9$.

Ilium-Ischium

Fig. 31, Finch Cr., R., internal aspect, B9656 (6), $\times 0.8$; Fig. 32, Recent, R., internal aspect, B7869, $\times 0.8$.

Scapula

Fig. 33, Finch Cr., R., dorsal aspect, B9670 (7), $\times 0.8$; Fig. 34, Finch Cr., R., ventral aspect, B9670 (3), $\times 0.8$; Fig. 35, Recent, R., dorsal aspect, W5655, $\times 0.8$.

Clavicle

Fig. 36, Finch Cr., L., external aspect, B9652 (9), $\times 0.8$; Fig. 37, Finch Cr., L., external aspect, B9652 (2), $\times 0.8$; Fig. 38, Recent, L. & R., external aspect, B7868, $\times 0.8$.

PLATE 11

Fossil and recent bones of *E. c. schlegeli* and *A. patagonica**E. c. schlegeli**Sternum*

Fig. 39, Finch Cr., L., lateral aspect, B9664 (5), $\times 0.7$; Fig. 40, Recent, L., lateral aspect, $\times 0.7$.

Tibio-tarsus

Fig. 41, Finch Cr., L., lateral aspect, B9646 (12), $\times 0.7$; Fig. 42, Recent, L., lateral aspect, B7868, $\times 0.7$.

*Aptenodytes patagonica**Humerus*

Fig. 43, Bauer Bay, R., ventral aspect, B10600 (1), $\times 1.05$; Fig. 44, Finch Cr., R., ventral aspect, B10595 (2), $\times 1.05$; Fig. 45, Recent, R., ventral aspect, B4356, $\times 1$.

Femur

Fig. 46, Finch Cr., R., ventral aspect, B10598 (1), $\times 1.2$; Fig. 47, Bauer Bay, R., ventral aspect, B10607 (2), $\times 1.2$; Fig. 48, Recent, R., ventral aspect, B4356, $\times 1.2$. Photographs 43-48 by I. Roper.